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Aggregate Resources Inventory
Paper 104

# Aggregate Resources Inventory of Towns of Grimsby and Lincoln and the Township of West Lincoln

Regional Municipality of Niagara
Southern Ontario

By Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey

1985

Ontario Ministry of Natural Resources

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# Contents


Abstract ..... 2
Introduction ..... 3
Part I - Inventory Methods ..... 4
Field and Office Methods ..... 4
Resource Tonnage Calculation Techniques ..... 4
Sand and Gravel Resources ..... 4
Bedrock Resources ..... 4
Units and Definitions ..... 5
Part II - Data Presentation and Interpretation ..... 6
Map 1 Distribution of Sand and Gravel Deposits ..... 6
Deposit Symbol ..... 6
Texture Symbol ..... 6
Map 2 Selected Sand and Gravel Resource Areas ..... 6
Site Specific Criteria ..... 7
Deposit Size ..... 7
Aggregate Quality ..... 7
Location and Setting ..... 7
Regional Considerations ..... 8
Map 3 Bedrock Resources ..... 8
Selection Criteria ..... 8
Selected Resource Areas ..... 9
Part III - Assessment of Aggregate Resources in Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 10
Location and Population ..... 10
Physiography and Surficial Geology ..... 10
Extractive Activity ..... 11
Selected Sand and Gravel Resource Areas ..... 11
Sand and Gravel Resource Areas of Tertiary Significance ..... 11
Bedrock Geology ..... 11
Selected Bedrock Resource Areas ..... 12
Selected Bedrock Resource Area 1 ..... 12
Selected Bedrock Resource Area 2 ..... 13
Summary ..... 13
References ..... 23
Appendix A - Suggested Additional Reading ..... 24
Appendix B - Glossary ..... 25
Appendix C - Geology of Sand and Gravel Deposits ..... 27
Appendix D - Geology of Bedrock Deposits ..... 29


## TABLES


1. Total Sand and Gravel Resources, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 14
2. Sand and Gravel Pits, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 15
3. Selected Sand and Gravel Resource Areas, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 16
4. Total Identified Bedrock Resources, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 17
5. Quarries, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 20
6. Selected Bedrock Resource Areas, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 21
7. Summary of Test Hole Data, Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 22


## FIGURES


1. Key Map Showing the Location of Towns of Grimsby and Lincoln and the Township of West Lincoln ..... 2
2. Bedrock Geology of Southern Ontario ..... 29

## MAPS (back pocket)

1. Distribution of Sand and Gravel Deposits, Towns of Grimsby and Lincoln and the Township of West Lincoln, Scale 1:50 000.
2. Selected Sand and Gravel Resource Areas, Towns of Grimsby and Lincoln and the Township of West Lincoln, Scale 1:50 000.
3. Bedrock Resources, Towns of Grimsby and Lincoln and the Township of West Lincoln, Scale 1:50 000.

# Aggregate Resources Inventory of the Towns of Grimsby and Lincoln and the Township of West Lincoln Regional Municipality of Niagara

by
Staff[1] of the Engineering and Terrain Geology Section

1. Project supervisor: Dale W. Scott; field work and report by G. Jones; compilation and drafting by staff of the Aggregate Assessment Office. The Mineral Resources Staff of Niagara District, Central Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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# Abstract

This report includes both an inventory and evaluation of sand and gravel, as well as bedrock resources, in the Towns of Grimsby and Lincoln and the Township of West Lincoln. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

The report area has very limited sand and gravel resources. The existing deposits are restricted in quality, thickness and extent. For these reasons, the deposits have not been selected for possible resource protection at the primary or secondary levels of significance. They have been classified as tertiary resources and may be suitable for some local extraction of low-specification aggregate. Presently, the municipalities in the study area must rely on bedrock-derived aggregate or imported sand and gravel to meet their aggregate needs.

The report area is underlain by a succession of shale, sandstone, limestone and dolostone of Ordovician and Silurian age. The dolostone of the Lockport Formation is well suited for the production of load- bearing aggregate and the shale of the Queenston Formation is important as a raw material in the clay products industry. Two areas underlain by bedrock of these formations have been selected for possible resource protection. An estimated 23,800 acres (9600 ha) are currently available for extraction, containing possible resources of 4250 million tons (3850 million tonnes).

**Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.**

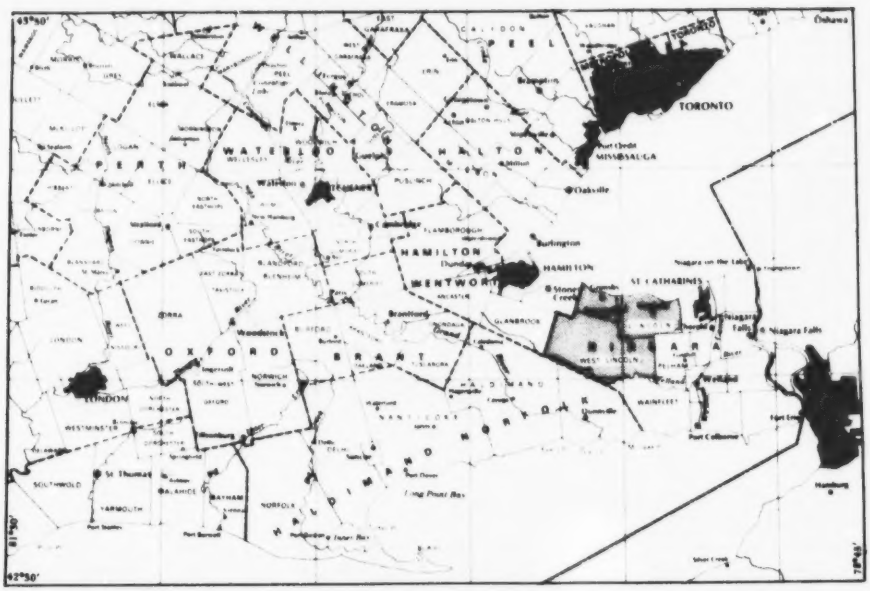



**Figure 1.** Key Map Showing the Location of the Towns of Grimsby and Lincoln and the Township of West Lincoln, Scale 1:1 800 000.

# Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1982, the total tonnage of mineral aggregates extracted was 101 million tons (92 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

**This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.**

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

# Part I — Inventory Methods

## FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing, hand augering and geophysical techniques are used to assess subsurface materials. Airphotos at various scales are used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100- pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests along with petrographic analyses are performed.

Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey. In areas of limited subsurface exposure, test holes are drilled and geophysical surveys using hammer seismic equipment are undertaken. The symbols for and locations of sample and test hole sites along with geophysical traverse lines are noted on Map 1.

In the office, the field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

## RESOURCE TONNAGE CALCULATION TECHNIQUES

### SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

*Tonnage = Area x Thickness x Density Factor*

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

### BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The

measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

**UNITS AND DEFINITIONS**

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

# Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

## MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

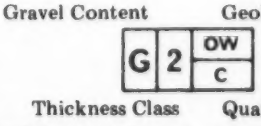
Map 1 is derived from existing surficial geology maps of the area or from airphoto interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

### DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:




This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

### TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The information from which these symbols are derived has been plotted in grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol. Geophysics lines are shown on the map by a line symbol.

## MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Al-

though deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

**Selected Sand and Gravel Resource Areas of primary significance are not permanent, single, land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.**

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

## SITE SPECIFIC CRITERIA

### Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

### Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the litholgy of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes, pits or sample sites have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

### Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on ex-

tractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

### REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

## MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource ares. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected drill hole which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

### SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

## SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approch. First, quality and quantity variations are graduai. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

**Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.**

# Part III — Assessment of Aggregate Resources in the Towns of Grimsby and Lincoln, and the Township of West Lincoln

## LOCATION AND POPULATION

The report area includes the Towns of Grimsby and Lincoln and the Township of West Lincoln. These municipalities occupy areas of 16,046 acres (6494 ha), 37,771 acres (15 286 ha) and 92,683 acres (37 509 ha), respectively, in the northwestern part of the Regional Municipality of Niagara. The Towns of Grimsby and Lincoln are situated along Lake Ontario while the Township of West Lincoln is located immediately to the south. The study area is shown on parts of the Dunnville (30 L/13), Hamilton-Grimsby (30 M/4), Niagara (30 M/3) and Welland (30 L/14) map sheets of the National Topographic System at a scale of 1:50 000.

The Regional Municipality of Niagara was formed in 1970 and involved the rearrangement and amalgamation of several municipalities which existed prior to 1970. The geographic townships of Caistor, Gainsborough and South Grimsby were incorporated into the Township of West Lincoln while the Town of Grimsby includes North Grimsby geographic township. The amalgamation of the geographic townships of Clinton and Louth formed the Town of Lincoln.

The population of the report area was 40 042 in 1982, an increase of approximately 5 percent since 1972 (Ontario Ministry of Municipal Affairs and Housing 1983; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). Major population centres in the area include the communities of Grimsby, Beamsville, Vineland, Jordan Station and Smithville. Outside these communities a large percentage of the population are rural-residential inhabitants or are engaged in farming. North of the prominent Niagara Escarpment, which trends east-west across the northern part of the report area, a large proportion of the land is used for fruit production and residential development, while the land south of the escarpment is suitable for general agricultural uses.

The area north of the escarpment is part of an important transportation corridor linking such major population centres as Toronto, Hamilton and St. Catharines in southern Ontario to the United States. The Queen Elizabeth Way, a major multilane highway, traverses the northern part of the area near Lake Ontario. The report area is also served by King's Highway 20 along with regional and local road systems which form a well developed grid pattern. Rail lines of the Canadian National and Toronto, Hamilton and Buffalo Railways are also important transportation linkages in the area.

## PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of unconsolidated sediments, including sand and gravel deposits, are the result of glacial activity which took place during the Late Wisconsinan Substage of the Pleistocene Epoch, informally known as the 'Great Ice Age'. This substage, which lasted from approximately 23 000 to 10 000 years ago, was marked by the repeated advance and melting back of massive, continental ice sheets.

The oldest surficial sediment known in the report area is the Halton Till (Karrow 1963). This clay to clayey silt till was deposited by the Ontario-Erie glacial lobe which advanced in a southwesterly direction out of the Lake Ontario basin into the Lake Erie basin (Feenstra 1981; in prep. c). Although the till is often covered by younger sediments, it is exposed at several locations in the report area, notably along the crests of the Vinemount and Niagara Falls Moraines, and along the base of the Niagara Escarpment. The moraines were probably formed during temporary halts of the retreating ice margin (Feenstra 1981; in prep. c). The Niagara Falls Moraine trends westward from Grassie to the western boundary of the Township of West Lincoln while the subsequently deposited Vinemount Moraine is located along the top of the Niagara Escarpment. An older moraine, known as the Fort Erie Moraine, may also traverse the study area south of the Niagara Falls Moraine, but is completely buried beneath younger sediments (Feenstra 1975; in prep. c). Till has little value as aggregate because of its high silt and clay content.

As the ice margin retreated northeastward to a position along the top of the Niagara Escarpment, where the Vinemount Moraine was formed, several glacial lakes occupied the area south of the ice (Feenstra 1981; in prep. c). In the deep waters of these lakes, clay and silt were deposited forming the Haldimand Clay Plain (Chapman and Putnam 1966) which occupies the Niagara Peninsula southward from the Niagara Escarpment to Lake Erie. An isolated body of silt and sand was also deposited in these waters along the flank of the Vinemount Moraine near Beamers Falls.

Subsequent retreat of the ice margin away from the Niagara Peninsula into the Lake Ontario basin resulted in the impoundment of glacial waters between the Niagara Escarpment and the ice sheet (Feenstra 1981; in prep. c). The highest level these waters reached is marked by two small beach deposits near Campden, located just above the Niagara Escarpment in the northeastern part of the report area (Feenstra 1981). The lake levels subsequently lowered and formed glacial Lake Iroquois. A wave-cut scarp, located along Regional Road 81, marks the shoreline of this lake. In the shallow waters of the lake, north of the scarp, glaciolacustrine sediments consisting of silty fine to medium sand were deposited. Beach sand and gravel were also deposited at the shores of the lake. Limited amounts of aggregate may be available from these beach deposits. In the deeper waters of the lake, silt and clay were deposited. The land covered by Lake Iroquois together with small terraces of till below the escarpment form the physiographic region known as the Iroquois Plain (Chapman and Putnam 1966).

After the final withdrawal of the ice sheet, alluvium was deposited near Grimsby and along several creeks and rivers in the area.

## EXTRACTIVE ACTIVITY

Several quarries have been developed in the report area and most are located along the Niagara Escarpment in bedrock of the Lockport Formation. In addition, one quarry has been developed north of the Niagara Escarpment in the Queenston Formation. At the time of writing, four quarries were licenced to operate having a total area of 907 acres (367 ha). The Towns of Grimsby and Lincoln, as well as the Township of West Lincoln, were designated in 1972 under the Pits and Quarries Control Act. Since the designation of the municipalities, records of the total annual production from all licenced sources have been maintained by the Niagara District Office of the Ontario Ministry of Natural Resources. The average annual production in the nine-year period between 1972 and 1980 has been approximately 1.3 million tons (1.2 million tonnes).

As the report area has a limited supply of sand and gravel, the municipalities must rely on bedrock-derived aggregate or imported sand and gravel to meet most of their needs. However, limited quantities of low-specification construction aggregate may be available for local use from the area's existing granular resources. Previous work concerning the industrial mineral resources in the area include reports by Vos (1969c), Telford and Narain (1980) and the Regional Niagara Planning and Development Department (1981).

## SELECTED SAND AND GRAVEL RESOURCE AREAS

As the sand and gravel deposits delineated on Map 2 grade fine for most aggregate uses or contain low available resources, no deposits have been selected for resource protection. They have been designated as tertiary resources, however, and some of the deposits, notably the beach deposits, may be suitable for local use within the area. Although these are not the 'best' resources, they should be considered as part of the area's aggregate supply. The tertiary resources occupy an area of 7300 acres (2950 ha) and contain resources of 142 million tons (129 million tonnes).

### SAND AND GRAVEL RESOURCES OF TERTIARY SIGNIFICANCE

Several beach deposits located near Vineland in the Town of Lincoln consist of gravelly sand but are restricted in respect to both thickness and areal extent. Based on analysis of a sample taken from similar beach material east of the report area, Feenstra (1981) reports that these deposits may contain weathered material, and deleterious amounts of shale and siltstone derived from the underlying Halton Till. Although these deposits are probably not suitable for high-specification aggregate use, limited amounts of low-specification aggregate suitable for local use in the area may be available.

The remaining tertiary resources in the town consist of alluvium or glaciolacustrine sand and are generally too fine for use as road- building or construction aggregate (Feenstra 1981).

## BEDROCK GEOLOGY

The study area is underlain by a succession of shale, sandstone, limestone and dolostone of Ordovician and Silurian age. Drift overlying the bedrock is generally thinnest in the northern part of the area with bedrock outcrops especially abundant along the length of the Niagara Escarpment. The Niagara Escarpment is a major bedrock feature in southern Ontario, and near Grimsby the escarpment attains a height of 275 feet (84 m) above the Iroquois Plain. East of Grimsby the relief of the escarpment is somewhat subdued as a broad, sloping, bedrock bench exists between the escarpment and the ancient Lake Iroquois shoreline (Chapman and Putnam 1966).

The Queenston Formation, the oldest bedrock unit present in the area, underlies the Iroquois Plain and forms the base of the Niagara Escarpment. The formation consists of red shale although occasional beds of mottled, green shale may be present (Liberty et al. 1976 a, b). Where the formation is close to the surface its occurrence is often indicated by the existence of brick-red-coloured soils. Major surface outcrops of this formation occur near Grimsby, Beamsville and Vineland. The Queenston shale, although too soft for use as load- bearing aggregate, is a resource of provincial significance for structural clay products and has been selected for possible resource protection in the report area.

The Queenston Formation is overlain by a succession of sandstone, shale, limestone and dolostone of the Cataract and Clinton Groups which form much of the face of the Niagara Escarpment. Although these groups have not been quarried recently in the report area, some of the constituent formations, notably the Whirlpool Formation, have been extracted for a variety of construction products elsewhere in southern Ontario. The Whirlpool sandstone is the lowermost formation belonging to the Cataract Group and directly overlies the Queenston shale. The sandstone has been quarried for building stone at several places along the Niagara Escarpment, but in the report area surface exposure of the formation is very restricted and it has not been selected for resource protection. Several other formations of the Cataract and Clinton Groups overlie the Whirlpool sandstone, most of which are not well suited for aggregate production. The formations which belong to the Cataract and Clinton Groups have not been mapped separately on Map 3 as they are extremely limited in extent.

The Cataract and Clinton Groups are overlain by the erosion- resistant dolostone of the Lockport Formation which forms the cap- rock of the Niagara Escarpment and underlies much of the clay plain south of the escarpment in the northern part of the study area. The Lockport Formation, a traditional source of quality aggregate in the Niagara Peninsula, comprises three members which have been selected for possible resource protection. The fine- to medium-grained, medium- to massive-bedded, porous and fossiliferous dolostone of the Gasport Member is the lowermost member of the formation (Liberty et al. 1976 a, b). The Gasport Member is well suited for the production of a range of aggregate products and most quarries in the report area have been developed in this member.

The Gasport Member is overlain by the very fine-grained dolostone of the Goat Island Member. In places, chert is abundant in the Goat Island dolostone and is usually concentrated near the base of the formation (Hewitt 1960). The member has been extracted for a range of aggregate products in the Niagara Peninsula. Where it is abundant, chert may restrict high-specification use of the dolostone. Both the Goat Island and Gasport Members have been grouped together on Map 3.

The upper limit of the Goat Island Member is marked by the appearance of the dark brown, thin-bedded, very fine-grained dolostone of the Eramosa Member. Bituminous or shaly partings are common in this upper member of the Lockport Formation and gypsum and chert nodules may be abundant. The member has been extracted to produce a wide variety of crushed stone products for road-building and construction purposes. However, Vos (1969c) notes that lateral lithological variations may prevent its use in some areas, therefore specific sites for extraction should be thoroughly tested before development.

The Guelph Formation overlies the Lockport Formation in the southern part of the study area. The massive-bedded, fine-grained dolostone of the Guelph Formation usually has a high chemical purity and is a valuable raw material for numerous industrial applications (Liberty et al. 1976 a, b). The rock, however, is soft and generally not well suited for use as load-bearing aggregate. The formation is predominantly covered by thick drift in the report area with the exception of several relatively small areas near the contact between the Guelph and Lockport Formations where overburden is less than 25 feet (8 m) thick. It may be possible to extract the Guelph Formation along with part of the underlying Lockport Formation in these areas, but quality data for the Guelph dolostone in the study area are lacking and it has not been selected for possible resource protection.

The youngest bedrock unit in the area is the Salina Formation which overlies the Guelph dolostone along the southern boundary of the Township of West Lincoln. The Salina Formation consists of argillaceous dolostone and shale with lenses of gypsum and other evaporitic materials (Telford and Tarrant 1975 a, b). The formation has been mined for gypsum elsewhere in southern Ontario, but has little value as aggregate.

## Selected Bedrock Resource Areas

Two areas located in the northern part of the study area have been selected for possible bedrock resource protection. The bedrock in these areas is overlain by less than 25 feet (8 m) of drift and consists of the Lockport and Queenston Formations. The Lockport dolostone is generally well suited for the production of load-bearing aggregate while the Queenston shale is an important raw material in the production of brick, tile and other clay products. The selected bedrock resource areas occupy a total available area of 23,800 acres (9600 ha) and contain resources of 4250 million tons (3850 million tonnes). The resource areas are readily accessible by both road and rail.

It should be stressed that intense land use competition in many parts of the report area may restrict the amount of land available for possible extractive development. Considerable portions of the resource areas along the escarpment may be unavailable as they lie within the policy areas of the Niagara Escarpment Commission. The presence of residential and other development along with the existence of valuable fruit growing lands, which are concentrated north of the escarpment on the Iroquois Plain, may also limit the availability of the resources. There exists, however, considerable latitude in the identification of specific sites for possible extractive development in the resource areas. It should also be noted that resources within the intensely developed areas within the cultural constraint boundaries surrounding Grimsby, Beamsville, Vineland and Smithville have not been selected for resource protection.

### SELECTED BEDROCK RESOURCE AREA 1

Five areas, labelled 1a to 1e on Map 3, make up Selected Bedrock Resource Area 1. Less than 25 feet (8 m) of overburden overlies the Lockport Formation in this Area. The bedrock in Area 1a consists of the Gasport and Goat Island Members of the formation. The Eramosa Member together with part of the underlying Goat Island and Gasport Members have been selected for possible resource protection in Areas 1b, 1c, 1d and 1e. With the exception of quarry no. Q6, all quarries developed in the study area are located in Area 1.

Area 1a is a strip of bedrock located south of the Niagara Escarpment. Eleven quarries have been developed in this Area including two licenced sources. Most of the identified quarries, with faces ranging from 5 to 45 feet (1.5 to 14 m), have been developed in the Gasport Member of the Lockport Formation. However, Hewitt (1960) reports that 6 feet (2 m) of chert-free Goat Island dolostone overlies the Gasport Member in the north face of licenced quarry no. Q4. Faces in the quarry range from 20 to 35 feet (6 to 11 m) and in places the Decew Formation of the Clinton Group is exposed on the quarry floor. A wide variety of products are produced in the quarry including concrete stone, hot-laid asphaltic stone and sand, and granular base course. Gabion stone and agricultural lime are also produced. Similar products may be produced from the presently undeveloped areas in Selected Bedrock Resource Area 1a.

The thickness of the Gasport and Goat Island Members varies considerably in the Niagara Peninsula (Liberty et al. 1976 a, b). The Gasport Member varies from 45 feet (14 m) at the Niagara gorge to 21 feet (6 m) near Grimsby and less than 2 feet (0.6 m) at Fruitland while minimum thicknesses of 18 and 25 feet (5 and 8 m) are known for the Goat Island Member. Based on quarry exposures in the report area, a workable thickness of 35 feet (11 m) has been estimated for the two members. The members, nevertheless, may be considerably thinner along the Niagara Escarpment and substantially thicker near their contact with the overlying Eramosa dolostone.

Areas 1b, 1c, 1d, and 1e are underlain by bedrock of the Eramosa Member of the Lockport Formation. Two licenced quarries have been developed in Area 1d (quarry nos. Q1 and Q2). Faces in quarry no. Q1 range from 60 to 70 feet (18 to 21 m) while a 20-foot (6 m) excavation was observed in quarry no. Q2.

Products produced from the Eramosa dolostone in quarry no. Q1 include crushed stone for concrete and granular base course. Armour stone, metallurgical stone, agricultural lime and some hot-laid asphaltic stone products are also produced. Near the base of the quarry, gypsum and chert nodules are common in several beds and these beds are selectively extracted to produce granular base course as the nodules restrict higher quality use of the aggregate. Although the Eramosa dolostone is an important source of quality aggregate in southern Ontario, quality variations can occur in this member necessitating thorough testing of sites prior to extractive development.

An average thickness of 30 feet (9 m) has been estimated for the Eramosa Member (Liberty et al. 1976 a, b), however, the member may locally exceed 70 feet (21 m) as indicated in quarry no. Q1. Since the underlying members of the Lockport Formation are also suited for extractive development, a 60-foot (18 m) workable thickness estimate has been adopted for Areas 1b, 1c, 1d and 1e.

Resource Area 1 occupies a total of 31,000 acres (12 500 ha), exclusive of licenced areas. Cultural constraints and previous extraction reduce the area currently available to 20,600 acres (8300 ha). Assuming workable thickness estimates of 35 feet (11 m) for Area 1a and 60 feet (18 m) for Areas 1b to 1e, available bedrock resources total 3600 million tons (3250 million tonnes).

### SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 is composed of two areas, designated 2a and 2b on Map 3. Area 2 is situated on the Iroquois Plain between Grimsby and Vineland in areas where the Queenston shale is overlain by less than 25 feet (8 m) of drift. The Queenston shale, although too soft for use as load-bearing aggregate, is the major raw material for several brick and tile plants in southern Ontario.

One quarry (quarry no. Q6) has been developed in the Resource Area. The shale extracted from this site was used primarily for the production of brick throughout much of the early history of extraction and later solely for tile manufacture (Guillet 1967). Faces in the quarry range from 10 to 15 feet (3 to 5 m) high and expose soft red shale with occasional harder fragments and green shale beds. Although the quality of the Queenston shale as a raw material in the clay products industry is generally high, several factors influence the suitability of the material. Excessive hardness and brittleness as well as irregular and excessive amounts of gypsum and green shale may restrict the quality of the shale (Proctor and Redfern Limited 1978). Therefore, the quality of the material should be tested prior to extractive development.

The thickness of the Queenston shale in the Niagara Peninsula has been estimated to be about 700 feet (213 m) (Liberty et al. 1976 a, b). Since the total thickness of the formation would probably not be extracted because of engineering and economic considerations, a workable thickness of 60 feet (18 m) has been estimated for the formation for the purpose of resource tonnage calculation. This workable thickness value represents an estimation of the potential depth of extraction and as most shale operations are relatively shallow, extraction to this depth may not occur.

Selected Bedrock Resource Area 2 totals 5600 acres (2270 ha), of which 3200 acres (1300 ha) are presently available for extraction when cultural constraints and previous extraction are considered. Assuming a workable thickness of 60 feet (18 m), available shale resources are estimated to be 640 million tons (580 million tonnes).

## SUMMARY

The Towns of Grimsby and Lincoln and the Township of West Lincoln have only limited resources of sand and gravel. The existing resources are either too fine grained for most aggregate uses or contain low available resources. Small quantities of aggregate may be available from several beach deposits in the Town of Lincoln.

Since the report area contains very little sand and gravel, the municipalities in the area must rely on bedrock-derived or imported aggregate to meet their needs. Two areas have been selected for possible resource protection in the northern part of the study area. The bedrock units selected include the Lockport Formation dolostone which has been a traditional aggregate source in the Niagara Peninsula and the Queenston Formation shale, a valuable raw material in the clay products industry.

Within the report area there exist valuable fruit growing lands, concentrations of residential and other developments, and the Niagara Escarpment, a prominent natural feature in southern Ontario. The study area also contains important bedrock resources suitable for both aggregate and clay product uses. Intense land use competition in parts of the resource areas may restrict the amount of land available for possible extractive development. There exists, however, considerable latitude in the identification of specific sites for possible extractive development in the resource areas and care should be taken to ensure the continuing availability of sufficient material to meet future needs.

Enquiries regarding the Aggregate Resources Inventory for the Towns of Grimsby and Lincoln as well as the Township of West Lincoln should be directed to the Ontario Ministry of Natural Resources, either at the Niagara District Office, Highway 20, Box 1070, Fonthill, Ontario, L0S 1E0 (Tel. (416) 892-2656) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203).

**TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN*.**

| 1<br>Class No. | 2<br>Deposit Type (see Appendix C) | 3<br>Areal Extent Acres (Hectares) | 4<br>Original Tonnage Millions of Tons (Tonnes) |
|---|---|---|---|
| TOWN OF GRIMSBY | | | |
| 3 | S-LP | 320 | 6 |
| | | (130) | (5) |
| 4 | S-LP | 185 | 2 |
| | | (75) | (2) |
| | | 500 | 8 |
| | | (202) | (7) |
| TOWN OF LINCOLN | | | |
| 3 | S-LB | 130 | 2 |
| | | (53) | (2) |
| | S-LP | 6600 | 132 |
| | | (2650) | (120) |
| 4 | S-LB | 31 | <1 |
| | | (12) | (<1) |
| | | 6800 | 134 |
| | | (2750) | (122) |
| TOWNSHIP OF WEST LINCOLN | | | |
| 3 | S-AL | 16 | <1 |
| | | (6) | (<1) |
| | | 7300 | 142 |
| | | (2950) | (129) |

N.B. Minor variations in all tables are caused by rounding of data.
*Deposits within cultural constraint boundaries surrounding Beamsville, Grimsby, Vineland and Smithville have been omitted on all tables.

**TABLE 2. SAND AND GRAVEL PITS, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN.**

| 1<br>No. | 2<br>MTC<br>No. | 3<br>Owner/<br>Operator | 4<br>Lot | 5<br>Con. | 6<br>Licenced<br>Areas<br>Acres<br>(Hectares) | 7<br>Face<br>Height<br>Feet<br>(Metres) | 8<br>% Gravel |
|---|---|---|---|---|---|---|---|
| | | | | -NONE- | | | |

N.B. Minor variations in all tables are caused by rounding of data.

**TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN.**

| 1<br>Deposit No. | 2<br>Unlicenced Area<br>Acres (Hectares) | 3<br>Cultural Setbacks<br>Acres (Hectares) | 4<br>Extracted Area<br>Acres (Hectares) | 5<br>Available Area<br>Acres (Hectares) | 6<br>Estimated Deposit Thickness<br>Feet (Metres) | 7<br>Available Aggregate<br>Millions of Tons (Tonnes) |
|---|---|---|---|---|---|---|
| | | | -NONE- | | | |

N.B. Minor variations in all tables are caused by rounding of data.

**TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN**

| 1<br>**DRIFT THICKNESS**<br>Feet<br>(Metres) | 2<br>**FORMATION** | 3<br>**ESTIMATED DEPOSIT THICKNESS**<br>Feet (Metres) | 4<br>**AREAL EXTENT**<br>Acres (Hectares) | 5<br>**ORIGINAL TONNAGE**<br>Millions of Tons<br>(Tonnes) |
|---|---|---|---|---|
| TOWN OF GRIMSBY | | | | |
| 0-3<br>(0-1) | Lockport<br>(Eramosa<br>Member) | 30<br>(9) | 16<br>(6) | 2<br>(2) |
| 3-25<br>(1-8) | Lockport<br>(Eramosa<br>Member) | 30<br>(9) | 2010<br>(810) | 217<br>(197) |
| 25-50<br>(8-15) | Lockport<br>(Eramosa<br>Member) | 30<br>(9) | 1360<br>(550) | 147<br>(133) |
| | | | 3400<br>(1380) | 365<br>(330) |
| 0-3<br>(0-1) | Lockport<br>(Goat Island &<br>Gasport<br>Members) | 35<br>(11) | 1060<br>(430) | 134<br>(122) |
| 3-25<br>(1-8) | Lockport<br>(Goat Island &<br>Gasport<br>Members) | 35<br>(11) | 5600<br>(2270) | 710<br>(640) |
| 25-50<br>(8-15) | Lockport<br>(Goat Island &<br>Gasport<br>Members) | 35<br>(11) | 1400<br>(570) | 176<br>(160) |
| | | | 8100<br>(3300) | 1020<br>(920) |
| 0-3<br>(0-1) | Clinton &<br>Cataract<br>Groups | 60<br>(18) | 530<br>(214) | 105<br>(95) |
| 3-25<br>(1-8) | Clinton &<br>Cataract<br>Groups | 60<br>(18) | 22<br>(9) | 4<br>(4) |
| | | | 550<br>(222) | 109<br>(99) |
| 0-3<br>(0-1) | Queenston | 60<br>(18) | 770<br>(310) | 152<br>(138) |
| 3-25<br>(1-8) | Queenston | 60<br>(18) | 380<br>(154) | 75<br>(68) |
| 25-50<br>(8-15) | Queenston | 60<br>(18) | 840<br>(340) | 166<br>(150) |
| | | | 1990<br>(800) | 395<br>(360) |
| | | | 14,000<br>(5700) | 1890<br>(1720) |

N.B. Minor variations in all tables are caused by rounding of data.

**TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN**

| 1<br>**DRIFT THICKNESS**<br>Feet<br>(Metres) | 2<br>**FORMATION** | 3<br>**ESTIMATED DEPOSIT THICKNESS**<br>Feet (Metres) | 4<br>**AREAL EXTENT**<br>Acres (Hectares) | 5<br>**ORIGINAL TONNAGE**<br>Millions of Tons<br>(Tonnes) |
|---|---|---|---|---|
| TOWN OF LINCOLN | | | | |
| 0-3<br>(0-1) | Lockport<br>(Eramosa Member) | 30<br>(9) | 430<br>(174) | 46<br>(42) |
| 3-25<br>(1-8) | Lockport<br>(Eramosa Member) | 30<br>(9) | 4950<br>(2000) | 540<br>(490) |
| 25-50<br>(8-15) | Lockport<br>(Eramosa Member) | 30<br>(9) | 3650<br>(1480) | 395<br>(360) |
| | | | 9000<br>(3650) | 980<br>(890) |
| 0-3<br>(0-1) | Lockport<br>(Goat Island & Gasport Members) | 35<br>(11) | 1500<br>(610) | 189<br>(171) |
| 3-25<br>(1-8) | Lockport<br>(Goat Island & Gasport Members) | 35<br>(11) | 5100<br>(2060) | 640<br>(580) |
| 25-50<br>(8-15) | Lockport<br>(Goat Island & Gasport Members) | 35<br>(11) | 3000<br>(1210) | 380<br>(345) |
| | | | 9600<br>(3900) | 1210<br>(1100) |
| 0-3<br>(0-1) | Clinton & Cataract Groups | 60<br>(18) | 500<br>(202) | 99<br>(90) |
| 3-25<br>(1-8) | Clinton & Cataract Groups | 60<br>(18) | 560<br>(227) | 111<br>(101) |
| 25-50<br>(8-15) | Clinton & Cataract Groups | 60<br>(18) | 550<br>(222) | 109<br>(99) |
| | | | 1610<br>(650) | 320<br>(290) |
| 0-3<br>(0-1) | Queenston | 60<br>(18) | 1460<br>(590) | 290<br>(265) |
| 3- 25<br>(1-8) | Queenston | 60<br>(18) | 4750<br>(1920) | 940<br>(850) |
| 25-50<br>(8-15) | Queenston | 60<br>(18) | 4550<br>(1840) | 900<br>(820) |
| | | | 10,800<br>(4350) | 2130<br>(1930) |
| | | | 31,000<br>(12 500) | 4650<br>(4200) |

N.B. Minor variations in all tables are caused by rounding of data.

**TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN**

| 1<br>**DRIFT THICKNESS**<br>Feet<br>(Metres) | 2<br>**FORMATION** | 3<br>**ESTIMATED DEPOSIT THICKNESS**<br>Feet (Metres) | 4<br>**AREAL EXTENT**<br>Acres (Hectares) | 5<br>**ORIGINAL TONNAGE**<br>Millions of Tons<br>(Tonnes) |
|---|---|---|---|---|
| TOWNSHIP OF WEST LINCOLN | | | | |
| 25-50<br>(8-15) | Salina | 60<br>(18) | 40<br>(16) | 8<br>(7) |
| 3-25<br>(1-8) | Guelph | 60<br>(18) | 1930<br>(780) | 420<br>(380) |
| 25-50<br>(8-15) | Guelph | 60<br>(18) | 8500<br>(3450) | 1840<br>(1670) |
| | | | 10,400<br>(4200) | 2260<br>(2050) |
| 0-3<br>(0-1) | Lockport<br>(Eramosa<br>Member) | 30<br>(9) | 150<br>(61) | 16<br>(14) |
| 3-25<br>(1-8) | Lockport<br>(Eramosa<br>Member) | 30<br>(9) | 10,300<br>(4150) | 1110<br>(1010) |
| 25-50<br>(8-15) | Lockport<br>(Eramosa<br>Member) | 30<br>(9) | 11,100<br>(4500) | 1200<br>(1090) |
| | | | 21,600<br>(8700) | 2330<br>(2110) |
| 0-3<br>(0-1) | Lockport<br>(Goat Island &<br>Gasport<br>Members) | 35<br>(11) | 170<br>(69) | 21<br>(19) |
| 3-25<br>(1-8) | Lockport<br>(Goat Island &<br>Gasport<br>Members) | 35<br>(11) | 175<br>(71) | 22<br>(20) |
| | | | 345<br>(140) | 43<br>(39) |
| | | | 32,500<br>(13 200) | 4650<br>(4200) |
| TOTAL REPORT AREA | | | 78,000<br>(31 500) | 11,200<br>(10 200) |

N.B. Minor variations in all tables are caused by rounding of data.

**TABLE 5. QUARRIES, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN.**

| 1 NO. | 2 MTC NO. | 3 OWNER/ OPERATOR | 4 LOT | 5 CON. | 6 LICENCED AREA Acres (Hectares) | 7 FACE HEIGHT Feet (Metres) |
|---|---|---|---|---|---|---|
| LICENCED QUARRIES | | | | | | |
| 1 | N3-35 | Nelson Aggregate Co. | Pt.20 | 9 | 110 (44) | 60-70 (18-21) |
| 2 | N3-36 | Walker Industries Ltd. | Pt.19 | 9 | 114 (46) | 20 small (6) excavation |
| 3 | - | Walker Industries Ltd. | Pt.5&6 5&6 | 5 6 | 260 (105) | 30-45 small (9-14) excavation |
| 4 | N3-23 | Walker Industries Ltd. | Pt.1,2 3,4 Pt.3,4 | 6 7 | 423 (171) | 20-35 (6-11) |
| | | | | | 907 (367) | |
| UNLICENCED QUARRIES* | | | | | | |
| 5 | - | Unknown | 11 | 2 | | 15-20 (5-6) |
| 6 | - | Unknown | 23 | 1 | | 10-15 (3-5) shale |
| 7 | N3-2 | Town of Lincoln (Gibson Quarries) | 17 | 5 | | 5 partially (1.5) rehabilitated |
| 8 | N3-2 | Town of Lincoln (Gibson Quarries) | 16 | 5 | | 10-15 under- (3-5) going rehabilitation |
| 9 | N3-2 | Town of Lincoln (Gibson Quarries) | 16 | 5 | | 5 under- (1.5) going rehabilitation |
| 10 | N3-2 | Town of Lincoln (Gibson Quarries) | 15 | 6 | | 10 under- (3) going rehabilitation |
| 11 | N3-2 | Town of Lincoln (Gibson Quarries) | 13 | 6 | | 5-10 under- (1.5-3) going rehabilitation |
| 12 | N3-2 | Town of Lincoln (Gibson Quarries) | 13 | 6 | | 30-40 under- (9-12)going rehabilitation |
| 13 | - | Unknown | 20 | 5 | | 10 (3) |
| 14 | - | Unknown | 11 | 8 | | 20-25 rifle (6-8) range |

N.B. Minor variations in all tables are caused by rounding of data.

*Abandoned quarries or wayside quarries operating on demand under authority of a permit.

**TABLE 6. SELECTED BEDROCK RESOURCE AREAS, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN.**

| 1<br>DEPOSIT NO. | 2<br>DEPTH OF OVERBURDEN<br>Feet (Metres) | 3<br>UNLICENCED AREA<br>Acres Hectares | 4<br>CULTURAL SETBACKS<br>Acres (Hectares) | 5<br>EXTRACTED AREA<br>Acres (Hectares) | 6<br>AVAILABLE AREA<br>Acres (Hectares) | 7<br>ESTIMATED WORKABLE THICKNESS<br>Feet (Metres) | 8<br>AVAILABLE RESOURCES<br>Millions of Tons (Tonnes) |
|---|---|---|---|---|---|---|---|
| TOWN OF GRIMSEY | | | | | | | |
| 1a | 0-25 | 6700 | 1880 | 20 | 4800 | 35 | 600 |
| | (0-8) | (2700) | (760) | (8) | (1940) | (11) | (540) |
| 1b | 3-25 | 1220 | 380 | 0 | 840 | 60* | 181 |
| | (1-8) | (495) | (154) | (0) | (340) | (18) | (164) |
| 1d | 0-25 | 800 | 220 | 0 | 580 | 60* | 125 |
| | (0-8) | (325) | (89) | (0) | (235) | (18) | (113) |
| | | 8700 | 2480 | 20 | 6200 | | 910 |
| | | (3500) | (1000) | (8) | (2500) | | (830) |
| TOWN OF LINCOLN | | | | | | | |
| 1a | 0-25 | 6300 | 1700 | 50 | 4550 | 35 | 570 |
| | (0-8) | (2550) | (690) | (20) | (1840) | (11) | (520) |
| 1d | 0-25 | 5100 | 2100 | 0 | 3000 | 60* | 650 |
| | (0-8) | (2060) | (850) | (0) | (1210) | (18) | (590) |
| 2a | 0-25 | 1050 | 550 | 20 | 480 | 60 | 95 |
| | (0-8) | (425) | (222) | (8) | (194) | (18) | (86) |
| 2b | 0-25 | 4600 | 1900 | 0 | 2700 | 60 | 540 |
| | (0-8) | (1860) | (770) | (0) | (1090) | (18) | (490) |
| | | 17,000 | 6200 | 70 | 10,700 | | 1860 |
| | | (6800) | (2500) | (28) | (4350) | | (1690) |
| TOWNSHIP OF WEST LINCOLN | | | | | | | |
| 1a | 0-25 | 345 | 105 | 0 | 240 | 35 | 30 |
| | (0-8) | (140) | (42) | (0) | (97) | (11) | (27) |
| 1b | 3-25 | 55 | 30 | 0 | 25 | 60* | 5 |
| | (1-8) | (22) | (12) | (0) | (10) | (18) | (4) |
| 1c | 3-25 | 6400 | 2400 | 0 | 4000 | 60* | 860 |
| | (1-8) | (2600) | (970) | (0) | (1620) | (18) | (780) |
| 1d | 0-25 | 3000 | 850 | 0 | 2150 | 60* | 465 |
| | (0-8) | (1210) | (345) | (0) | (870) | (18) | (420) |
| 1e | 0-25 | 950 | 480 | 0 | 470 | 60* | 102 |
| | (0-8) | (385) | (194) | (0) | (190) | (18) | (92) |
| | | 10,800 | 3850 | 0 | 6900 | | 1460 |
| | | (4350) | (1560) | (0) | (2800) | | (1320) |
| TOTALS FOR REPORT AREA | | | | | | | |
| 1 | | 31,000 | 10,100 | 70 | 20,600 | | 3600 |
| | | (12 500) | (4100) | (28) | (8300) | | (3250) |
| 2 | | 5600 | 2450 | 20 | 3200 | | 640 |
| | | (2270) | (990) | (8) | (1300) | | (580) |
| | | 36,500 | 12,500 | 90 | 23,800 | | 4250 |
| | | (14 800) | (5100) | (36) | (9600) | | (3850) |

N.B. Minor variations in all tables are caused by rounding of data.

*Workable thickness estimate for Areas 1b, 1c, 1d and 1e includes the Eramosa Member and part of the underlying Goat Island and Gasport Members.

**TABLE 7. SUMMARY OF TEST HOLE DATA, TOWNS OF GRIMSBY AND LINCOLN AND THE TOWNSHIP OF WEST LINCOLN.**

-NONE-

N.B. Minor variations in all tables are caused by rounding of data.

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# Appendix B — Glossary

***Abrasion resistance:*** Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

***Absorption capacity:*** Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

***Aggregate:*** Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

***Alkali-aggregate reaction:*** A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

***Blending:*** Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

***Cambrian:*** The first period of the Palezoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

***Clast:*** An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

***Crushable aggregate:*** Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

***Deleterious lithology:*** A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

***Devonian:*** A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

***Dolostone:*** A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

***Drift:*** A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

***Drumlin:*** A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

***Eolian:*** Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

***Fines:*** A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

***Glacial lobe:*** A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

***Gradation:*** The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

| | |
|---|---|
| Boulder | more than 200 mm |
| Cobbles | 75-200 mm |
| Coarse Gravel | 26.5-75 mm |
| Fine Gravel | 4.75-26.5 mm |
| Coarse Sand | 2-4.75 mm |
| Medium Sand | 0.425-2 mm |
| Fine Sand | 0.075-0.425 mm |
| Silt, Clay | less than 0.075 mm |

***Granular base course:*** Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

***Hot-laid (or asphaltic) aggregate:*** Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

***Lithology:*** The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

***Magnesium sulphate soundness test:*** This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

***Meltwater channel:*** A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

***Ordovician:*** an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

***Paleozoic Era:*** One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

***Petrographic examination:*** An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

***Pleistocene:*** An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

***Possible resource:*** Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

***Shale:*** A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

***Silurian:*** An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

***Soundness:*** The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

***Till:*** Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

***Wisconsinan:*** Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

# Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

## GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

***Ice-Contact Terraces (ICT):*** These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

***Kames (K):*** Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

***Eskers (E):*** Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

***Undifferentiated Ice-Contact Stratified Drift (IC):*** This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

***Outwash (OW):*** Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

***Alluvium (AL):*** Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

## GLACIOLACUSTRINE DEPOSITS

***Glaciolacustrine Beach Deposits (LB):*** These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

***Glaciolacustrine Deltas (LD):*** These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near- ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

***Glaciolacustrine Plains (LP):*** The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

## GLACIAL DEPOSITS

***End Moraines (EM):*** These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

## EOLIAN DEPOSITS

***Windblown Deposits (WD):*** Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

# Appendix D — Geology of Bedrock Deposits

## BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

### Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

### Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine- grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

### Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin- bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

### Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

### Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

### Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive- bedded, fine-to medium-grained dolostone. Thickness: Amabel Formation: maximum observed

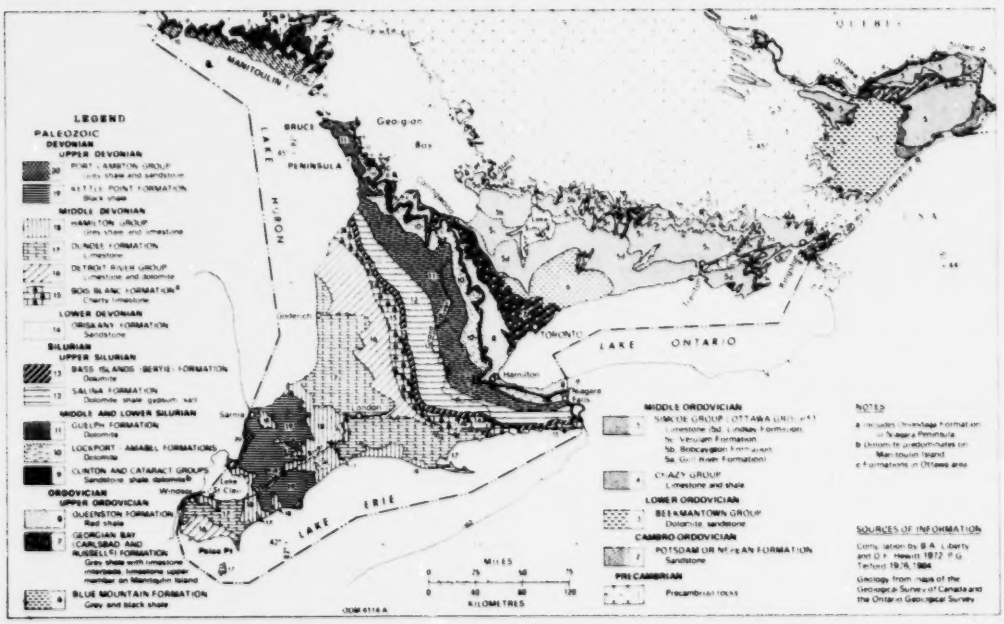


**Figure 2.** Bedrock Geology of Southern Ontario.

thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

#### Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium- grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey- brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

#### Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

#### Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

## BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

#### Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

#### Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

#### Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

#### Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

#### Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

## BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician) (Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

#### Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

**Queenston Formation (Upper Ordovician)**

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

## BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

**Nepean (Potsdam) Formation (Cambro-Ordovician)**

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

**Salina Formation (Upper Silurian)**

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

**Blue Mountain Formation (Upper Ordovician)**

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.